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A NOVEL EPOXY LACQUER FOR HIGH STRENGTH STEEL IN F-111 AIRCRAFT DURING OVERHAUL

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The Development of a Novel Epoxy Lacquer for Use on High Strength Steel Components of RAAF F-111 Aircraft During Overhaul

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Abstract

The corrosion inhibiting paint used on high strength steel (D6AC) components of RAAF F-111 aircraft is removed from the wing carry thru box and lower trap tank during deseal/reseal of integral fuel tanks and from the fuel flow holes and stiffener runouts during crack inspection of the wing pivot fittings. Following paint removal, a protective lubricant is applied to the exposed components during overhaul to inhibit corrosion and pitting of the D6AC steel. Adhesive paint failures have subsequently occurred following recoating of this steel in a number of F-111 aircraft as a result of incomplete removal of the lubricant. This report describes the development of an alternative temporary corrosion prevention coating to replace the protective grease. The replacement coating is an inhibited uncured epoxy resin system which is smear resistant, solvent removable and chemically compatible with the D6AC protective coating. Coating problems associated with the overhaul procedures are no longer being experienced since introduction of the epoxy lacquer into service by RAAF.

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The Development of a Novel Epoxy Lacquer for Use on High Strength Steel Components of RAAF F-111 Aircraft During Overhaul

1. *Introduction*

Deseal/reseal repairs of F-111 aircraft involve removal of the existing sealants and paints from the aircraft fuel tanks including the low carbon high strength steel (D6AC) wing carry thru box (WCTB). Likewise, crack inspection of the fuel flow/vent holes ("mouseholes") and stiffener runouts in the aircraft involves paint removal from the D6AC steel of the wing pivot fittings (WPFs). RAAF maintenance procedures specify that due to the corrosion growth rate of D6AC steel, the elapsed time that bare steel may be exposed to the atmosphere is to be held to an absolute minimum with a maximum allowable exposure time of one hour. If it is anticipated that the surface will not be protected within the hour then the bare steel is required to be temporarily protected by military specification lubricant MIL-C-16173 (preservation grease).

The moisture resistant MIL-C-16173 lubricant has recently been identified as being responsible for paint failures in the WCTB. The lubricant is also suspected to be responsible for paint failures in the WPFs. Delays on the return to service of two F-111 aircraft as a result of paint failures caused by grease residues have amounted to more than four months in the past year. Other significant delays have also occurred in previous years for similar reasons. The problems with the lubricant are complicated by the need for personnel to lie down to work in the WCTB which causes the inhibiting grease to be spread throughout the area by contact with clothing and shoes. This makes removal of the grease time consuming and difficult to achieve. Moreover, when the grease is diluted by solvents during cleaning, it is washed into seams and voids. When the paint is subsequently applied, the grease is leached out and coating adhesion is adversely affected.

RAAF advise that the time lost and the expense resulting from these in-service failures has become unacceptable. One of the F-111 aircraft undergoing deseal/reseal in the US has now been out of service for nearly five months. A number of problems have slowed the aircraft refurbishment schedule and the completion date may be further delayed following the finding in the WCTB that sealant could be peeled off by hand in strips up to 10 cm long. This was despite the fact that an air pressure check of the fuel tanks had indicated that a successful reseal had been accomplished following the resealing of all fuselage tanks.

It was found that while the sealant had adhered sufficiently to the new paint, the new paint had not effectively adhered to the walls and roof of the WCTB. Laboratory analysis revealed the presence of the D6AC MIL-C-16173 preservation grease. The grease had caused the non-adherence as a result of it being inadequately removed from the surfaces of the WCTB prior to painting. Approximately 30 per cent of the WCTB will require desealing/resealing. This situation is typical of other instances where delays of several months have occurred in the return of the aircraft to service.

In view of the problems arising from the use of the protective lubricant, RAAF Headquarters Logistic Command have sought assistance to identify and develop a paint or lacquer to replace the corrosion preventive grease. As a result of discussions, it was decided that an ideal replacement coating should have the following characteristics: compatibility with D6AC steel; a distinctive colour to aid identification when removal is required; ease of application; ease of removal (no worse than the grease); compatibility with (the existing) paint and a capacity to dry to a firm, non greasy finish. Moreover, there should be compatibility of the removal solvent with D6AC steel.

2. *Experimental*

2.1 *Materials*

A number of temporary corrosion preventive materials were assessed against the performance requirements listed in the Methods Section (2.2). Grease-type films, although not meeting these criteria, were included as a basis for comparison of corrosion protectiveness.

The temporary corrosion preventive coatings examined were:

(i) hydrocarbon greases,
(ii) cold application solvent deposited hydrocarbons,
(iii) hard resin films, and
(iv) novel epoxy lacquer

Specifically the following commercial and experimental materials were examined:

(i) **Hydrocarbon greases:** Preservac E (Mobil Oil Aust Ltd), Preservac THX (Mobil Oil Aust Ltd), Denso 305 (Denso Aust Pty Ltd).

(ii) **Cold application solvent deposited hydrocarbon:** Ensis HB (Shell Aust).

(iii) **Hard resin films:** Incralac (Wattyl-Sigma Pty Ltd).

(iv) **Epoxy lacquer:** the novel epoxy lacquer was formulated from long chain epoxy resins to which pigments and chromate inhibitor were added.

2.2 Methods

The temporary corrosion preventive coatings were evaluated by the following methods to determine their suitability for use on D6AC steel in F-111 aircraft.

2.2.1 *Compatibility with D6AC Steel*

The coating is required to be compatible with D6AC steel. This was assessed by reviewing the coating composition to determine the absence of acidic or basic components likely to cause hydrogen embrittlement.

2.2.2 *Colour of Temporary Coating*

The colour of the protective material, after drying, is required to be such that coating coverage could be easily determined in reduced lighting conditions as experienced in integral fuel tanks. The colour of the coating is required to be distinguishable from the paint coating used to permanently protect F-111 D6AC steel components in-service. This was assessed visually.

2.2.3 *Ease of Application*

The protective coating is required to show no grit, skinning, livering or excessive pigment flotation, and no more settling or caking than could be easily redispersed to a uniform and homogeneous condition. The coating is also required to show good working properties on reduction to spray consistency and dry to a uniform smooth surface free of runs. The film, after drying, is required to be free of blisters, streaks, coarse particles, cratering and other surface irregularities. This was assessed by inspection of the paint before and after application followed by further inspection of the coating on drying.

2.2.4 *Ease of Removal*

The protective material is required to be easily removed by neutral solvents. This was assessed by removal with both methyl ethyl ketone and the solvent MIL-C-38736.

2.2.5 *Compatibility of Removal Solvent with D6AC Steel*

The solvent or solvent mixture used to remove the protective coating is required to be compatible with D6AC steel (i.e. not cause corrosion or embrittlement). This was assessed by reviewing the solvent composition to determine the absence of acidic or basic components likely to cause embrittlement.

2.2.6 *Compatibility of In-Service Coating with Temporary Coating*

The composition of the protective coating is required to be such that trace residues remaining on the D6AC steel after solvent removal should not adversely affect application and adhesion of the coating used to protect D6AC steel components in-service. This was assessed by applying the in-service paint coating over traces of the temporary coating, allowing 72 hours drying time and immersing in MEK. Blistering of non-compatible coatings becomes apparent within 15 minutes.

2.2.7 *Drying of the Temporary Coating*

The temporary corrosion protective coating is required to dry to a firm hard finish to avoid smearing during tank maintenance operations. The coating is also required to dry hard within 30 minutes at 25°C and 50% RH. Smearing was assessed by rubbing the coating to determine whether the coating integrity was disrupted. Drying was assessed by the time taken to achieve tough dryness.

2.2.8 *Corrosion Resistance*

The temporary corrosion preventive coating is required to be blister-free and prevent mild steel panels from corroding when immersed for 24 hours in tap water.

3. Results

3.1 Suitability of Replacement Coatings

The results of examination of the alternative corrosion preventive coatings were as follows:

3.1.1 *Compatibility of Material with D6AC Steel*

All coatings examined were acid/alkali free and compatible with D6AC steel.

3.1.2 *Colour of Temporary Corrosion Preventive Coating*

All materials were unpigmented except the epoxy lacquer 2.1 (iv). The green pigmentation of the epoxy lacquer was distinct from the paint coating used to protect the D6AC steel during operational service.

3.1.3 *Ease of Application*

All materials were easily applied. All hard coatings met the requirement for grit, skinning, livering, settling and flotation.

3.1.4 *Ease of Removal*

All hard coatings were readily removed with MIL-C-38736 and MEK solvents as required. The greases were relatively easily removed, however determination of complete removal was difficult.

3.1.5 *Compatibility of Removal Solvent with D6AC Steel*

MIL-C-38736 removed all coatings and is compatible with D6AC steel.

3.1.6 *Compatibility of In-Service Coating with Temporary Coating*

(i) Residues of the hydrocarbon greases had a strongly adverse effect on the integrity of the D6AC protective paint film (Integral Fuel Tank Coating) and on its adhesion. Grease residues caused cratering and bubbling of the paint.

(ii) The adhesion of the D6AC protective coating appeared satisfactory when it was applied over traces of the acrylic lacquer, however the traces of acrylic lacquer under the coating made it more solvent sensitive than that of uncontaminated D6AC coating.

(iii) D6AC protective paint applied over light residues of the epoxy lacquer showed no loss in solvent resistance compared to D6AC paint alone.

3.1.7 *Drying of the Temporary Coating*

All of the solvent borne coatings dried within 25 minutes at 25°C and 50% RH.

3.1.8 *Corrosion Resistance*

All of the hydrocarbon greases protected the steel for the 24 hour trial immersion period. Pinhole corrosion occurred with the acrylic lacquer. The epoxy lacquer protected the steel substrate for the immersion period.

4. Discussion

There are a number of different types of compounds which have been developed previously for temporary corrosion protection. Generically, they may be divided into (i) hydrocarbon based materials (MIL-C-16173) and (ii) hard resin films (MIL-C-85054). Of the group (i) materials, the Australian Defence Specification "DEF (AUST) 1001 Temporary Corrosion Preventive" lists six categories of materials which are all hydrocarbon based. Of the group (ii) materials, MIL-C-85054 specifies the use of clear, dry, hard films for the protection of iron, aluminium and other metals. These protective coatings first came to the attention of TTCP countries in 1978. These coatings are commonly used in the storage of military equipment. A number of other specialized materials have also been developed such as water removable corrosion preventive coatings and peelable coatings which are unsuited for the present application.

The hard hydrocarbon film, Ensis HB, gave excellent corrosion resistance but was more difficult to remove than the smearable greases. Hydrocarbon residues from this material, like the smearable greases, had a strongly adverse effect on paint film formation and adhesion.

Of the hard resin based film temporary coatings, the clear acrylic lacquer failed to pass the corrosion resistance test. The clear nature of this film also made the degree of removal difficult to determine.

The epoxy lacquer met all of the requirements for a replacement "temporary corrosion preventive coating". This is not surprising since it was formulated from long chain epoxy compounds which form tough non-smearing films on solvent evaporation. It was reasoned that such films would avoid the problems presently encountered in the aircraft fuel tanks as (i) the solvents in the formulation are already used on D6AC steel and (ii) traces of the resin components of the lacquer are compatible with the D6AC protective paint. The lacquer also met the corrosion resistance and drying requirements.

The epoxy lacquer is compatible with the existing DeSoto anticorrosive paint. Small traces of the epoxy lacquer remaining after removal will be softened during application of the DeSoto coating. The epoxy lacquer will then react with components of the DeSoto coating and become a permanent part of the corrosion protection system.

5. Outcome

In view of the above results, the epoxy lacquer was recommended for trial on F-111 D6AC components at Amberley. This trial, carried out by RAAF personnel, demonstrated that the lacquer met all operational requirements. RAAF subsequently approved the epoxy lacquer for use on all F-111 D6AC components. Since that time (six months), no paint failures associated with residues have been reported.

6. Conclusions

The delays to F-111 aircraft repair procedures caused by paint failures resulting from grease residues had become unacceptable to the RAAF. Early reports on the introduction and performance of the novel epoxy lacquer replacement suggest that these delays may be eliminated with this replacement material.

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